TOPPAN
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Study of EUV Mask Defect Inspection and Repair Using Conventional Tools and Techniques

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Outline

1.Motivation

2.Experiments

3.Inspection evaluation result

4.Repair evaluation result

5.Summary

Motivation

■**EUV mask yield and defect inspection has been focused recently.**

■**At present situation, applied optical mask inspection and conventional repair technology have been used for EUV mask fabrication.**

Technical Issue on EUV Lithography

Rank	2005	2006	2007	2008	2009
1	Resist	Source	Source	Source	Mask
2	Source	Resist	Resist	Mask	Source
3	Mask	Mask	Mask	Resist	Resist

source: EUV Focus Areas 2005-2009 (SEMATECH)

EUV mask optical inspection performance and repair capabilities were evaluated by using existing tools.

Experimental Flow

Inspection

Sensitivity target definition

- ✓ Kirchhoff simulation

Off-focus inspection evaluation

- ✓ Contrast test
- ✓ Sensitivity vs. Contrast

Defect sensitivity analysis

- ✓ Clear extension defect
- ✓ Dark extension defect

Repair

Repair test (EB tool)

- ✓ Condition optimization

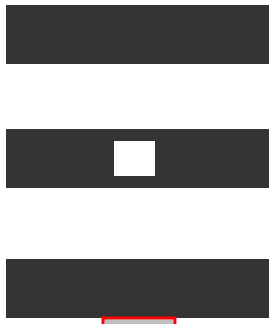
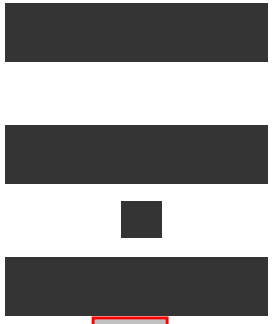
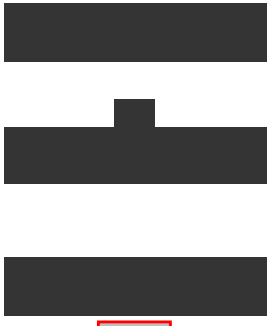
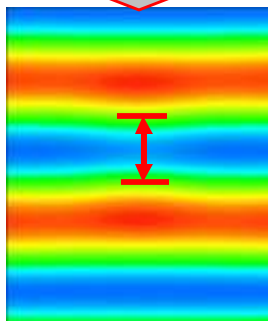
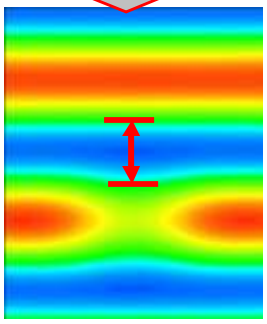
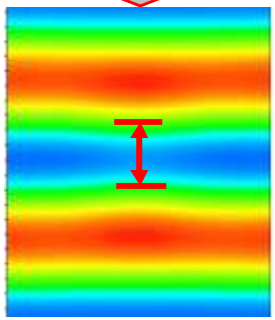
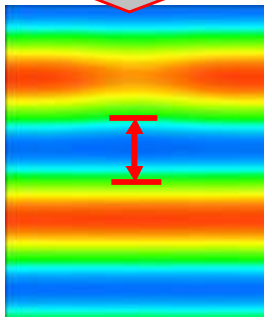
Time dependent change investigation

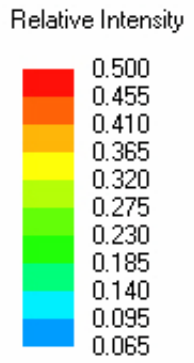
- ✓ Pattern profile variation

Pattern shape assessment

- ✓ Tilt SEM

Target Defect Size

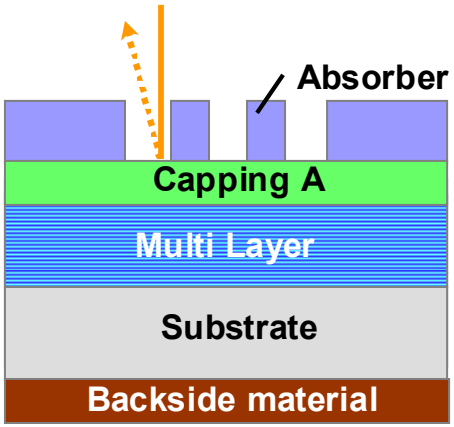
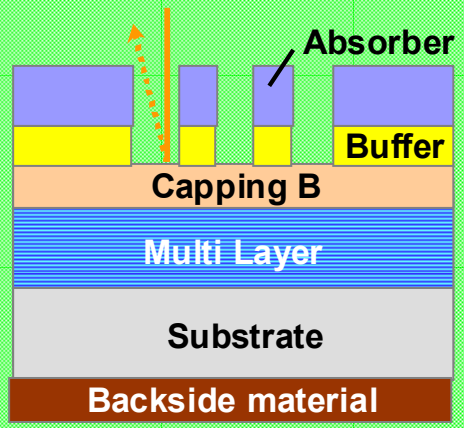
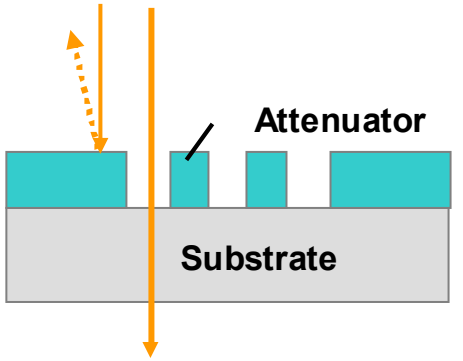
Mode	Pin hole	Pin dot	Clear extension	Opaque extension
Layout (on Mask)				
Aerial image (on Wafer)				



Simulator	Prolith v 12.02 (KLA-Tencor)
NA/Sigma	0.25 / 0.5
Method	Kirchhoff (2D)
Feature	HP 27nm Dense Line

Defect detection target
CD variation +/-10%

Materials

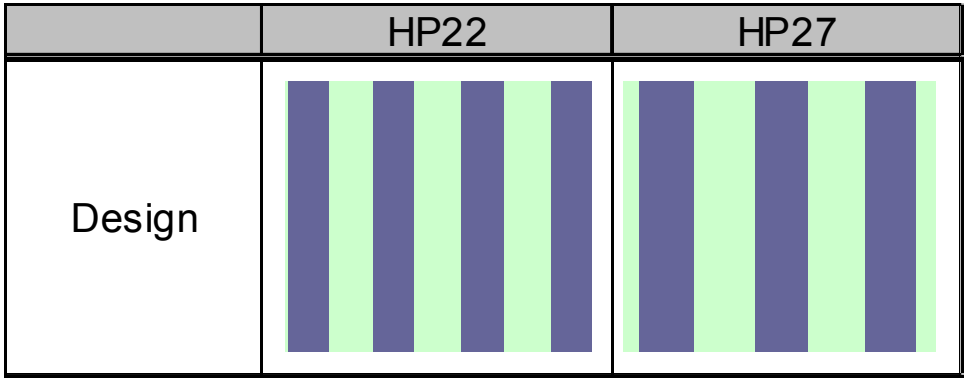
Type	EUV A :w/o buffer	EUV B :w/ buffer *	Optical Mask
Schematic Diagram			
Inspection	Reflected light only		Transmitted & Reflected

*EUV type B was evaluated in this study.

In case of EUV, defect sensitivity requirement needs to be achieved only by reflected light inspection.

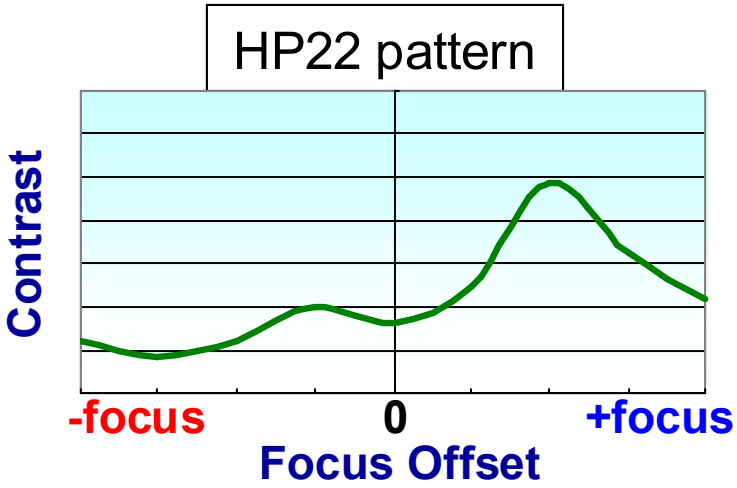
Image Contrast vs. Focus Offset - @257nm tool

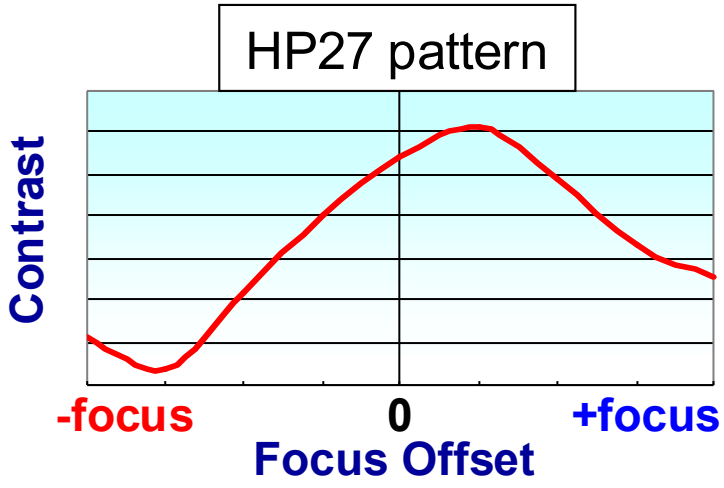
■**Checked image contrast variation on 257nm inspection tool.**



: Capping layer

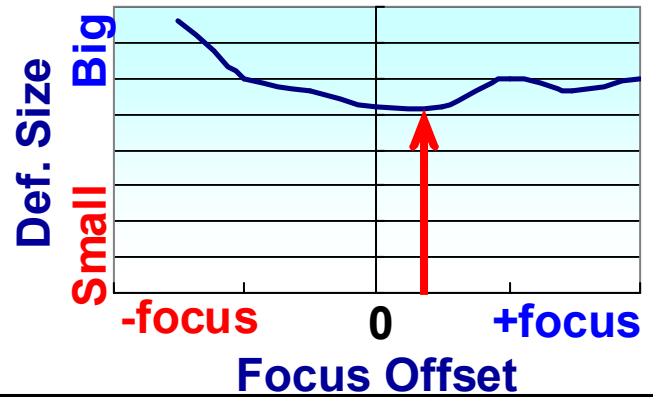
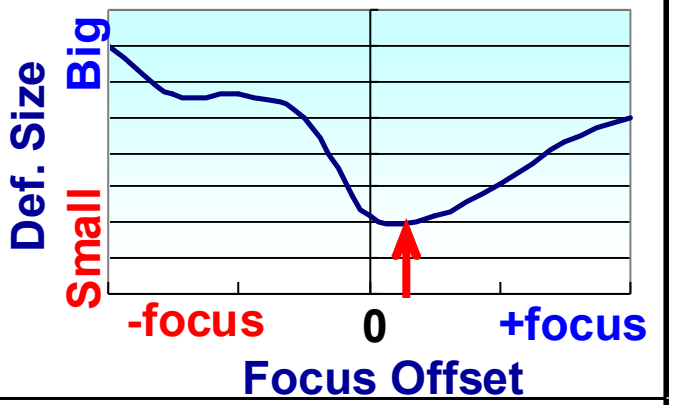
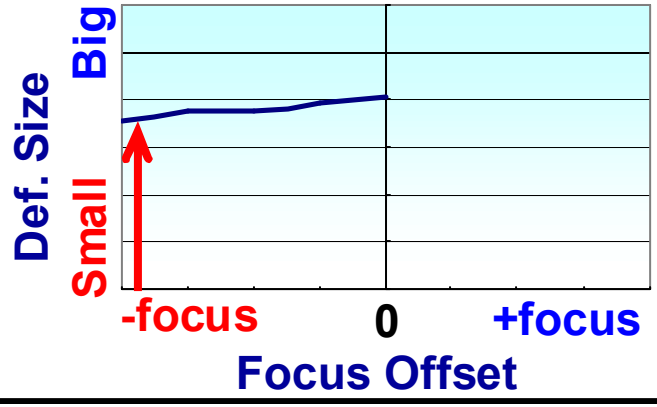
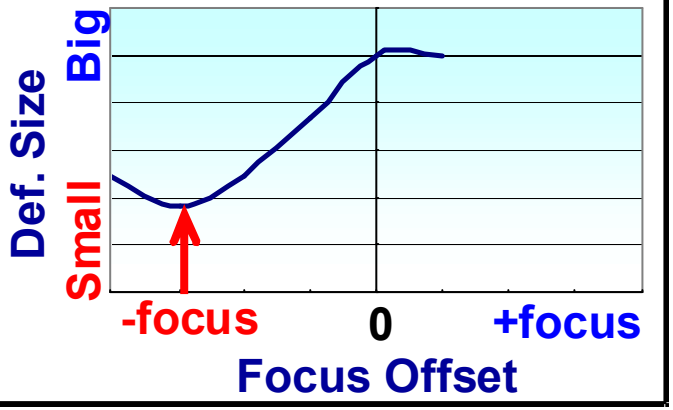
: Absorber





- Best contrast was not achieved at best focus point.
- Sensitivity may be varied by contrast difference.

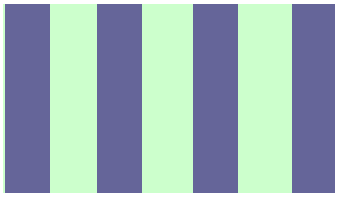
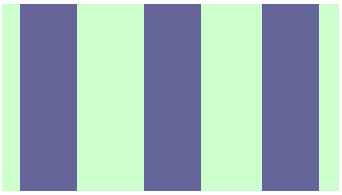
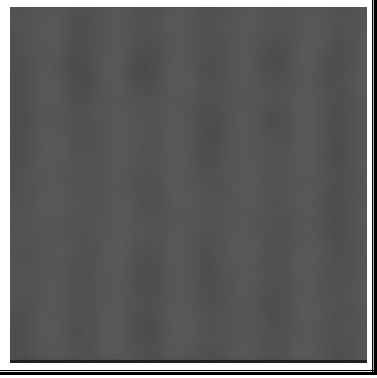
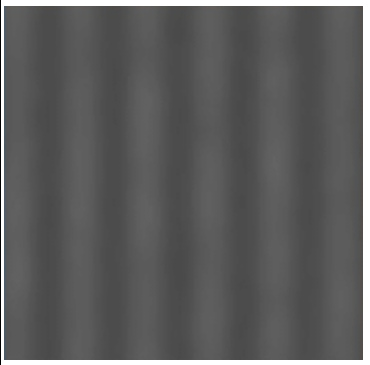
Sensitivity vs. Focus Offset -@257nm tool

Defect Type	HP22	HP27
Clear Extension		
Opaque CD error		

↑:Best Sensitivity

- Best sensitivity is not always achieved at best focus inspection.
- Defect sensitivity for each defect types could be differed from inspection conditions.

Image Contrast on 19xnm tool

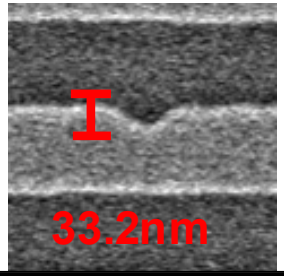
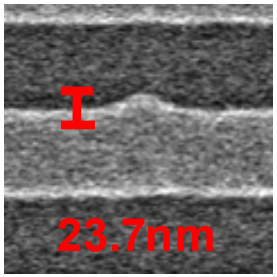
	HP22		HP27	
Design				
Focus Offset	Negative	Positive	Negative	Positive
Captured Image				

: Capping layer

: Absorber

- Contrast was changed by applying different focus offset.
- Need further investigation to know image contrast difference through different focus offset.

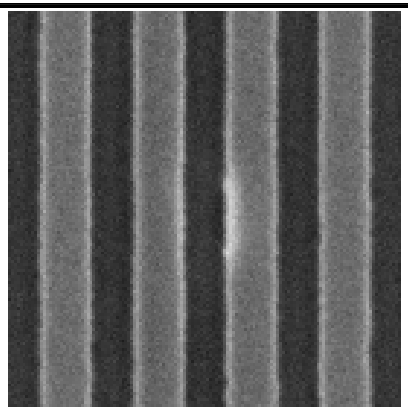
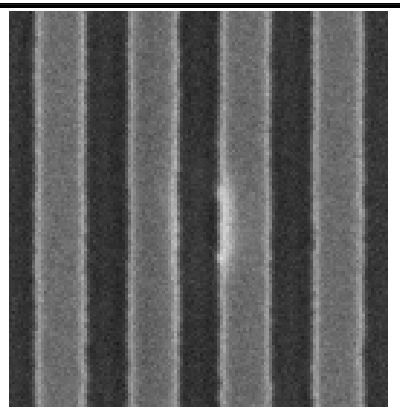
Defect Sensitivity Analysis on 19xnm Tool

	Defect & Target	257nm tool	19xnm tool	
			Negative focus	Positive focus
HP27				
				

 : Detected  : Not detected

- For these defect types, positive focus inspection detected target size defects.
- It seems that positive focus inspection is good for edge defects.
- Need further evaluation to verify the best inspection condition for other defect types.

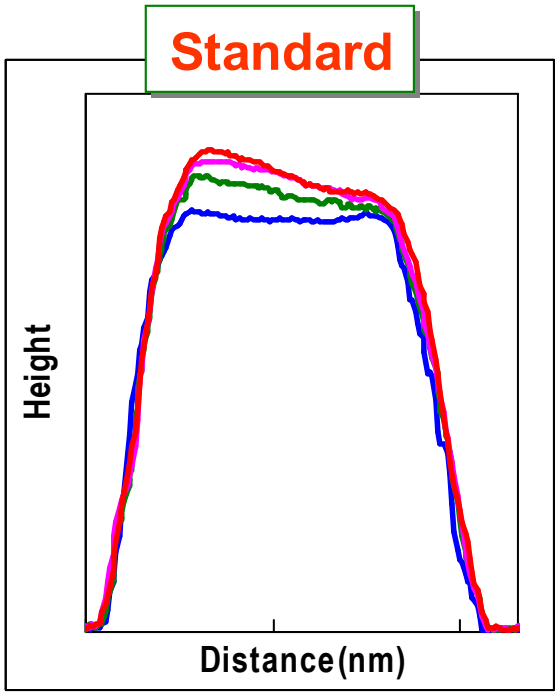
EUV Mask Repair Test

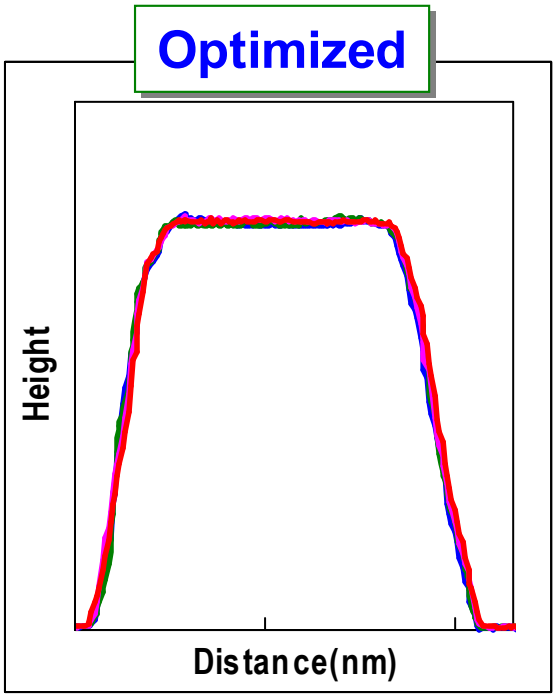
Recipe	A	B
Repair Tool	EB tool	
Condition	Standard condition	Optimized setting
Post Repair		

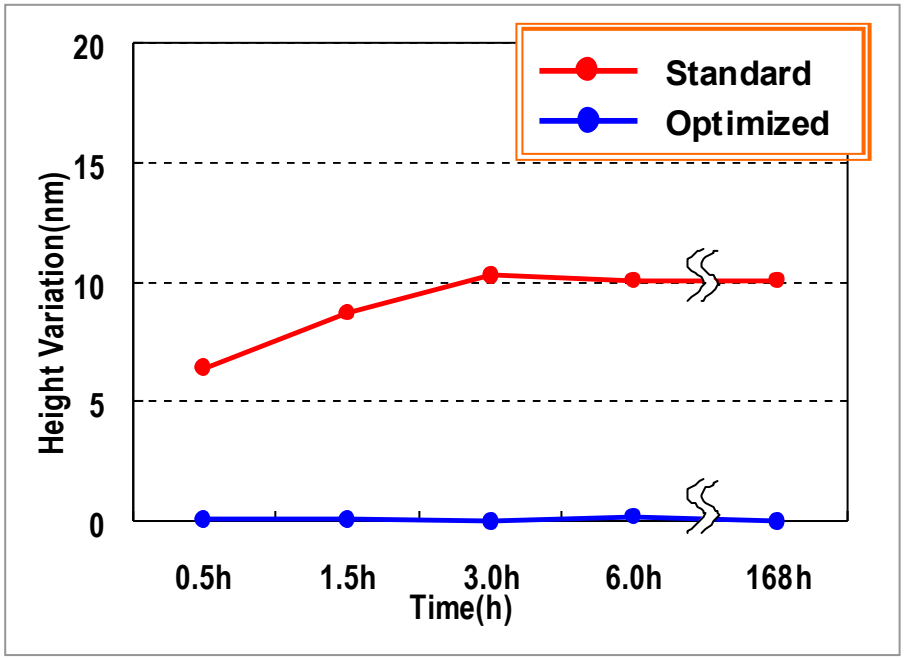
- Right after repair process, these repaired sites do not show any problem.
- But it is known that repaired pattern shape changes as time advances.

Defect Repair of EUV Masks

- In PMJ2010, repair performance with optimum setting was reported.





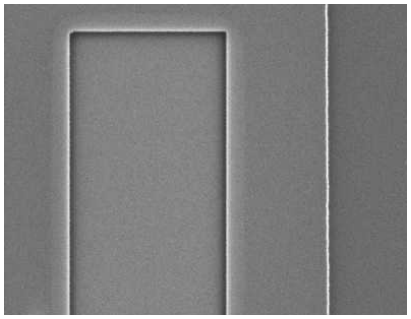
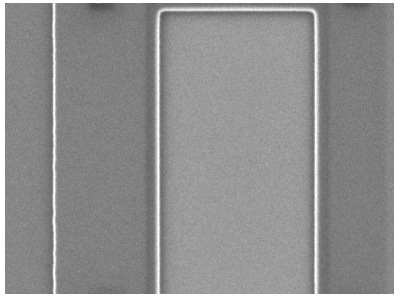
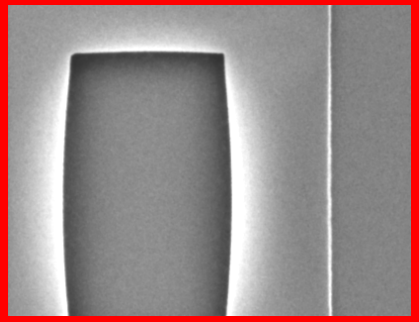
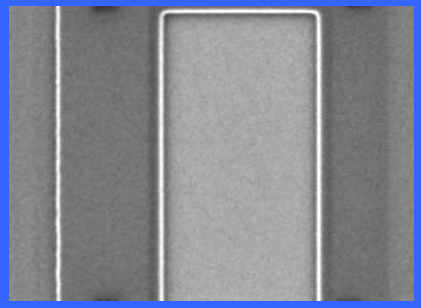


Reference (no defect)
post repair (0.5h)
post repair (1.5h)
post repair (3.0h)

- The optimum recipe was slightly sensitive.
- Tried to improve repair performance stability.

Time Dependent Change Comparison

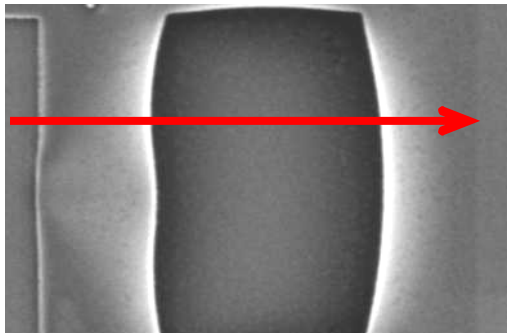
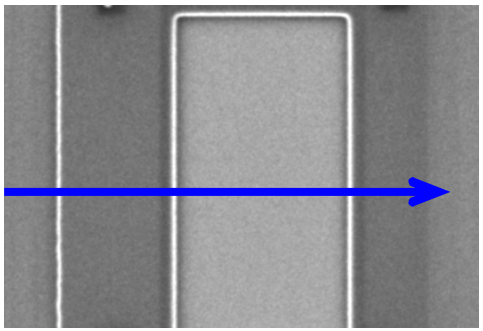
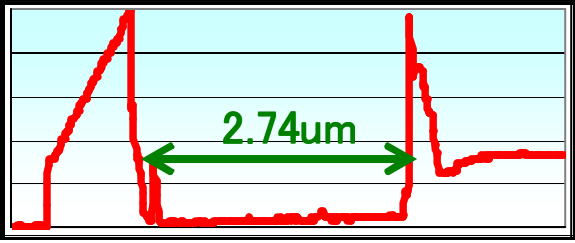
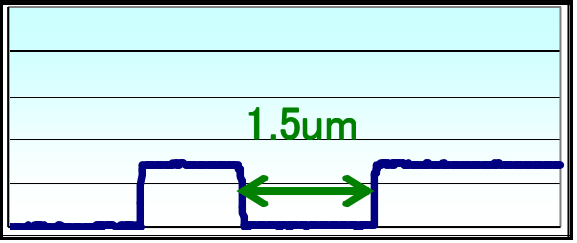
- For this test, dug 1.5um width hole with different recipe and observed the shape of the pattern.

Recipe	A (Standard)	B (Optimized)
Post Repair		
1 hour later		

- Under standard condition A, shape change was observed even after 1 hour since repair was done.
- No time dependent change happened under optimized condition B.

Repair Shape Assessment

- Checked repair shape after 1 day since repair was done.

Recipe	A	B
1 day after repair		
Cross section by AFM		

- Condition A showed dramatic shape change.
  - The size of the pattern grew almost double from original size.
- Condition B did not show any difference from original shape.
- The optimized condition does not appeared to cause time dependent change.

Summary

Inspection

- EUV mask inspection was performed by conventional optical inspection tool.
- Defect sensitivity for each defect types could be differed from inspection conditions.
- Inspection strategy needs to be considered how to detect all critical defects by minimum inspection times.

Repair

- Developed new recipe to improve post-repair pattern shape.
- Confirmed post-repair pattern shape was very stable.
- Succeeded to stabilize EUV mask repair quality.
- Need to evaluate new recipe is applicable for actual defect repair process.